

## **CMP PAD WITH LONG USER LIFE**

### **FIELD OF INVENTION**

The invention relates to wafer planarizing chemical mechanical polishing (CMP) systems.

### **BACKGROUND OF THE INVENTION**

With the growing demand for ever greater miniaturization of ULSI devices, planarization via CMP becomes an increasingly critical aspect in the fabrication sequence of semiconductor devices. The challenge stems, *inter alia*, from the multitude and differing nature of materials used in the various layers, the demanding geometries and aspect ratios of the structures, the ever present quest for improved IC device flatness and better yields via reduction of defects.

Broadly, there are known two types of CMP compositions and processes:

A. Slurry-based CMP, wherein abrasive particles contained in an aqueous suspension along with a host of other ingredients are delivered onto a pad, typically made of polyurethane, or polyurethane composites. This kind of CMP is also termed hereinafter “slurry-delivering pad”. The surface to be planarized rubbing against the rotating pad, resulting in levelling action via removal of protruding / uneven matter.

B. Fixed abrasive pads, wherein abrasive particles are embedded in the pad, and do not require extraneous delivery of slurry to the surface that is to be planarized.

The prior art recognizes shortcomings of slurry-delivering pads. These shortcomings are as listed below, are prompting the industry to often prefer the generally more costly fixed abrasive pads.

Some shortcomings of currently known slurry-based pads:

1. They gradually undergo changes during use, and can be prone to inconsistent and uneven slurry distribution across the polishing pad, leading to unsatisfactory planarity in the polished substrate.
2. Surfaces and pores of polishing pads tend to deteriorate, possibly as a result of hydrolytic exposure of the polyurethane surface to the slurry suspension, resulting in inconsistent performance.
3. Slurry-based polishing pads are relatively short-lived.

Above-enumerated shortcomings of slurry-based CMP systems, are generally not encountered in fixed abrasive polishing constructions, wherein the abrading layer is encapsulated in a binder, and engineered to achieve maximum flatness, that more consistently duplicates similar flatness or planarity in the wafer that is to be polished. However, fixed abrasive pads are not without some weaknesses.

Possibly the most salient benefit missing in fixed abrasive elements, is that slurry-based compositions can be formulated to contain, in addition to the abrasive particles, other needed chemical components, such as wetters, oxidants, leveling agents and the like, making the slurry suspension self-sufficient throughout the polishing operation. Indeed, in the case of fixed abrasive pads on the market today, needed chemicals i.e. oxidants, must be delivered separately, and it is perhaps for this reason that slurry-based chemical mechanical polishing systems are still practiced very widely, if not predominantly, in spite of their shortcomings as partially enumerated above.

Another major shortcoming of slurry-based systems resides in the gradual degradation of the pad, in the course of the polishing operation. While the precise

mechanism that causes degradation is not well understood and remains somewhat controversial, it seems that exposure of the pad surface to the slurry suspension results in the deformation of the pores / channels that are acting as transfer vehicles of the slurry to the surface that needs polishing. Regardless of the mechanism by which the pads lose efficiency and cannot “deliver” uniform planarization, experience shows that during its use the pores will be “smoothed” and the surface of the pad is “glazed” as opposed to its original, desired topography. One hypothesis of the prior art is assigning the cause the gradual, in use deterioration, to hydrolytic reactions of the outer surface of the pad, generally made of polyurethane or polyurethane composites, with the aqueous environment of the slurry, especially when the latter operates at neutral or alkaline pHs.

Additionally, pads tend to collect particulate debris of matter that is removed during planarization, further clogging up pores, grooves and thus aggravating processing problems.

The following prior art references are cited herewith, as partly indicative of pad-related concerns, and efforts to address them:

WO 03/038862 A2 to West, US 5489233 to Jenkins, US 5197999 to Thomas and US 2002098779 to Tsai.

Many, if not most prior art deficiencies are essentially related to short pad life, coupled with inconsistent / uneven slurry distribution and delivery, even before the pad reaches “terminal life” and needs to be discarded.. Indeed, as mentioned earlier, pores or channels in the pad tend to become filled with debris from particles of material being removed or polished away, and will therefore detract from efficient and uniform delivery of slurry to the substrate that is undergoing abrading or polishing. The prior art tries to overcome pad “fatigue” via a process known as conditioning, which essentially restores desired pad performance by removing or altering the deteriorated pad areas using a rotary disk whose upper surface contains protruding diamond particles that will remove the affected pad layer, or generate new alternative channels / pores.

US 20020098779 mentioned previously, attempts to reduce CMP dishing, a major challenge in planarization of copper interconnect devices by, for example, introducing metal such as copper into the grooves of the pad. The idea behind above application is to provide the pad with a metal, inter alia copper, that has “reductive properties” and thereby reduces galvanic attack of copper. The application highlights the enormous challenge of minimizing dishing, though its way to remedy dishing is not quite understood. .

## **SUMMARY OF THE INVENTION**

This invention addresses prior art shortcomings of slurry-based pads, making them perform more evenly /consistently, making fixed abrasive pads less indispensable.

Thus, the present invention provides a slurry-delivering pad with extended pad life. “Pad life” is understood in this invention to refer to the total number of polishes that the pad can provide with adequate performance, before it is discarded. The total number of polishes delivered by prior art pads is believed to be in the range of 200-400. The pad of the present invention is capable of consistent, uniform chemical mechanical polishing, without necessitating frequent pad conditioning. These properties are achieved by forming a more resilient outer surface, or “skin” on the pad.

The slurry-delivering pad of the invention is characterized by a robust outermost surface, that allows the pad to be easily and effectively cleaned of debris lodged in the pores/grooves of the pad using organic solvents or preferably emulsions, without sever attack, and/or distortion of the slurry delivering areas such as pores, grooves, etc.

“Outer surface” is defined in this invention as referring to the areas of the pad that come in contact with the substrate to be planarized, or areas of the pad that deliver the slurry suspension to the substrate, i.e. pores, grooves, orifices, and the like. Such outer surface will be generally distinguishable from the inner

structure of the pad because of different color, density, MW, hardness, etc., observable for instance, via cross-section coupled with instrumental analysis.

The slurry-delivering pad of the invention has incorporated therein, according to a preferred embodiment, at least into the outermost layer of the pad, a metal or metal compound that will lower the dissolution potential, i.e. driving force for galvanic attack, or erosion, of copper metal in the slurry media, that would otherwise take place and contribute to dishing. Consequently, the slurry-delivering pad of the invention is adapted to minimize dishing.

Again, the basic, though not limiting, consideration of this invention centers on generating a more durable outer surface, without necessarily altering, affecting bulk properties of the pad, or methods by which the pad is manufactured. The term “bulk properties” in this invention, is meant to describe “interior” “segments of the pad, meaning segments beyond the outer surface that comprises the pores/grooves, etc.

The model that will potentially illustrate the invention and thus assist in maximizing, fully exploiting its benefits and embodiments, proposes to focus on the outer surface as a distinct, somewhat separate “entity” of the pad, and is distinguishable therefrom, for example via instrumentation, as noted above.

The invention thus endeavors to form, an outermost layer, or “skin” on the pad that will lead to improved performance, by being more resilient, more durable. Preferably, such outermost surface is formed after the pad is manufactured, and preferably, though not limitingly, prior to its use. An alternate embodiment of the invention envisions forming or repairing the outer surface during CMP use of the pad intermittently, as needed.

There are numerous embodiments for forming an improved outer layer or surface of the pad, that can be implemented by one skilled in the art. Such embodiments can only be partly dealt with in this patent, but surely not exhaustively.

## DETAILED DESCRIPTION OF THE INVENTION

As mentioned earlier, the invention envisions reinforcing the outermost surface of the pad, to make the pad more durable, with more consistent overall performance. This reinforced outer surface is preferably at least 0.05 microns thick.

Conceptually but not limitingly, this can be done via two general approaches :

1. Modify the surface of the finished, as manufactured pad by subjecting it to radiation, selected from the group of EB, UV, IR and the like.
2. Apply a layer or film onto the pad. Such layer or film being designed to improve its CMP performance as deposited, or following its exposure to heat, or radiation as in # 1 above.

In addressing embodiments under # 1 above, one can be guided by radiation methods, technologies used in the field of industrial painting, powder coating, and the like. They are extensively used in the field of appliance, automotive, surface finishing, etc.

In effecting embodiments under # 2 above, it may be possible to deposit layers or films, such as for example teflon, that are strongly hydrophobic and also resilient to attack by slurry environments. Generally, such films may be deposited from organic solvent - based compositions, or from emulsions/microemulsions. Thickness of such layers will tend to be of the order of several Angstroms, but no more than several microns or often fractions thereof. Such films can be applied using techniques such as dip, spray, spin-coating, and the like.

As to radiation-sensitive, outer surface-forming films of this invention, they can be accessed from compositions and processes similar to those practiced in lithography, especially microlithography. In a preferred embodiment, the outer-surface films are obtained from negative-acting compositions, wherein radiation causes cross-linking, polymerization, etc. Also, while above mentioned films can be applied extraneously to the pad, one can envision incorporating radiation-

sensitive compounds into the bulk material of the pad, making radiation-curing of the outer surface an in-situ embodiment.

In additional embodiments under category # 2 above, a metal film is deposited on the surface of the pad. This can be embodied by vacuum metallization, sputtering, electroless plating, or the like. It is realized that metal films will need to be periodically renewed or redeposited, as they will be weakened or removed by wear, chemical attack of the slurry environment, or a combination of the two. It is easily seen that metal films that are resistant to attack will be preferred, but will by necessity need to be cost -affordable.

In choosing the appropriate metal film, one will preferably select a metal, alloy, or metal compound that will, additionally and synergistically, minimize dishing by lowering the dissolution EMF of copper, as mentioned before. Solely by way of cursory examples, and not limitingly, potential components of the outermost pad layer will comprise,  $\text{Cu}_2\text{O}$ ,  $\text{CuO}$ , finely divided Cu metal powder,  $\text{SnO}$ ,  $\text{SnO}_2$ , finely divided tin metal, combinations of the forementioned, or any other combinations that will reduce galvanic attack of copper interconnects, as described earlier.

Also, while instant invention is primarily addressing an improved slurry-delivering pad, some features and concepts thereof will potentially benefit fixed abrasive pads as well, and are within the spirit and scope of the invention.